IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT

In re application of: Kellar Autumn

Attorney Docket No.: LEWIP001

Application No.: 10/039,574

Examiner: Jeff H. Aftergut

Filed: January 2, 2002

Group: 1733

Title: ADHESIVE MICROSTRUCTURE AND METHOD OF FORMING SAME

DECLARATION UNDER 37 CFR § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Kellar Autumn, declare as follows:

1. I am the inventor of the subject matter described and claimed in the above-identified application.

2. I received a Bachelor of Arts degree in Mathematics and Biology from the University of California, Santa Cruz in 1988. I received a Doctorate of Philosophy in Integrative Biology from the University of California, Berkeley in 1995.

3. Since 1998, I have been a Professor of Biology at Lewis & Clark College, Portland, Oregon. In July 1999, I was also a visiting Assistant Professor at the University of California, Berkeley. A copy of my Curriculum Vitae is attached.

4. I am a co-author of the Nature article, published June 8, 2000, entitled "Adhesive Force of a Single Gecko Foot-hair". ("Autumn, et al."). I am also a co-author of the article from Solid-State Sensor and Actuator Workshop, published June 2000, entitled "Adhesion Force Measurements on Single Gecko Setae". ("Liang, et al.").

5. I was intimately involved in the work and experiments that are the subject of the Autumn et al. and Liang et al. articles. In fact, I was the lead author on the study of the Autumn et al. article.

6. This work involved, as the articles disclose, a technique for measuring the adhesive force of a single gecko foot-hair. The technique employed a MEMS sensor. The sensor was a micromachined, dual-axis piezoresistive sensor.

7. The cantilever sensor was fabricated on a single-crystalline silicon wafer. It had two independent force sensors, each with one predominant direction of compliance. The perpendicular or vertical sensor consisted of a thin triangular probe. The parallel force sensor was composed of four long slender ribs. A special 45° oblique ion implantation allowed piezoresistive and conductive regions to be implanted on both the parallel and perpendicular surfaces simultaneously. Forces applied to the tip of the sensor were resolved into these two orthogonal directions (parallel and perpendicular), and the forces were measured by the changes in resistance of the piezoresistors. The backside of the sensor was used to provide a smooth surface for setal adhesion.

8. The setae was glued to the end of a # 2 insect pin by an epoxy. Manipulation of the seta was done by means of the pin. That is, for force measurements, the seta was brought into contact with the backside sensor surface by manipulation of the pin.

9. Under the conditions of these experiments, the pin was not flexible. It was effectively rigid.

10. The intent of the experiments was to eliminate compliance everywhere but the single seta. This was why we had such difficulty in attachment of a single seta. It took months to get preload to be appropriate for the single seta.

11. I can say with certainty that the pin functioned as a rigid base for the single setae. If the pin was flexible, which it was not, we would not have used it and would have chosen a stiffer pin. The forces generated by preloading a single 100 micron gecko seta were much too low to cause a significant deflection of the tip of the pin. I will calculate the tip deflection under a perpendicular

load of 10 micro-Newton, the greatest preload used in the Liang et al. and Autumn et al. articles (see figure 2b).

12. From Gere JM and Timoshenko SP. (1984), Mechanics of materials, Independence, KY: Thomson Brooks/Cole, for a cantilever beam under a lateral load F at its tip, the resulting tip displacement due to bending is:

FL^3 / 3EI,

where L is the length, E is the elastic modulus of the material, and I is the area moment of inertia of the cantilever. For a cylindrical cantilever where I = pi * R^4 / 4, and in the case of the insect pin, R = 0.45 millimeters (mm), with length of 3.8 centimeters (cm), and using E = 210 GPa (http://web.mit.edu/2.003/www/labs/lab1/prelab1.pdf) for spring steel, the tip deflection for a load of 0.00001 N is 2.7e-08 meters, or 27 nanometers. This is trivial. The change in position or orientation of the rigid pin with loading is negligible compared with its unloaded configuration.

13. A tip deflection of a 3.8 cm long pin by only 27 nanometers is so small that the pin is effectively rigid. We would need approx. 30 micrometer diameter pin to yield a 1 mm tip deflection under the 10 micro-Newton load.

14. In the case of the flexible beam used in the experiments that my current patent application is based on, the beam was flexible. That is, a new layer of compliance is provided above the setae. The flexible beam provides a sufficient preload force to achieve good contact of the setal array to, for example, a substrate. Thus, the flexible beam of my invention uses appropriate flexibility to yield proper preload of a setal array or protrusions while maintaining substantially parallel alignment of the setal array or protrusions with a surface. The flexible beam is designed such that under any operational load or preload, the loading of the beam acts to deflect it to a new position and orientation which improves engagement.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both (under Section 1001 of Title 18 of the United States

Code), and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Kellar Autumn

Kellar Autumn

9-15-2005

Date